SECTION 6B - VERIFICATION WELL MONITORING, INTEGRITY TESTING, AND CONTINGENCY PLAN

6B.1 Fluid Sampling and Analysis

The verification well will be installed only for the purpose of monitoring subsurface conditions and will not be used for injection of CO_2. Therefore, there are no (pre-injection) waste sampling requirements associated with these wells.

6B.1.1 Sampling frequency – N/A
6B.1.2 Analysis parameters – N/A
6B.1.3 Sampling location – N/A
6B.1.4 Detailed waste analysis plan – N/A

6B.2 Monitoring Program

Refer to 6A.2 for a description of the overall monitoring program.

This section (6B) is intended to supplement section 6A by providing additional details which are specific to Verification Well #2.

One monitoring well (herein referred to as verification well) will be drilled and completed to allow observations which will measure formation pressures and help track the location of the CO_2 plume resulting from injection at nearby injection well(s). These observations will be available via various options including direct measurements of pressure and temperature, collection of samples for chemical analysis if required, and through wireline measurements such as pulsed neutron logs. This verification well, to be named Verification Well #2, will be drilled vertically and located in a position which is anticipated to be proximal to the outside edge of the CO_2 plume front at a time of 3 to 5 years after injection begins. See Section 5 for the modeling based predictions of the spatial plume front.

A multi-zone monitoring system will be deployed to allow measurement of fluid pressures and temperature, collection of fluid samples if required, and performance of standard hydrogeologic tests at and between multiple intervals. Five monitoring zones are planned in this monitoring well; these will be located throughout the Mt. Simon Sandstone. The exact location of the monitoring zones will be determined based on drilling and geologic information, obtained during the drilling of the wells.. IBDP results to date will also be used to select the zones within the Mt. Simon to be monitored. The monitoring program will be utilized to confirm the presence of annular seals between monitoring zones.

After a petrophysical review of all available data, the chosen zones will be developed by perforating short discrete intervals (e.g. 2 to 3 feet each) in the well casing. The multi-zone monitoring system will be installed inside the well casing, using hydraulically set packers to seal the annular space between the perforations and prevent fluid flow between perforations. The system is compatible with the expected site subsurface environment (brine and CO_2). Elastomers used in the packer elements will be CO_2 resistant.

6B.2.1 Recording Devices

Modular zonal management system description
The proposed multi-zone monitoring system integrates series of packers, flow control valves, and pressure/temperature measurements in modular assemblies.

A single electronic control line will be used to communicate with all of the pressure and temperature gauges. High resolution gauges will be used to monitor pressure and temperature.
System Operation
Fluid pressure measurements can be collected from each zone in the verification well simultaneously.

The primary purging and well development will be carried out prior to installation of the multi-zone monitoring system.

6B.2.2 Control and Alarm System for the Well Monitoring and Maintenance N/A

6B.2.3 USDW Monitoring in Area of Review See Section 6A.2.3

6B.2.4 Detailed Groundwater Monitoring Plan N/A

6B.2.5 Tracking Extent and Pressure of CO_2 plume See Section 6A.2.5

6B.2.6 Surface Air and and/or Soil gas monitoring See Section 6A.2.6

6B.3 Mechanical Integrity Tests During Service Life of Well

To verify the "absence of significant leaks," the downhole and surface pressures, along with the casing-tubing annulus pressure, will be monitored and recorded. Routine monitoring activities that will be used as part of the Mechanical Integrity Testing System are described below:

1) Monitoring of the pressure or the absence of pressure inside the casing/tubing annulus above the uppermost packer will be carried out continuously by means of a pressure gauge at the wellhead. An unexpected change in the annulus pressure will be investigated to ensure that it is not an indication of the loss of a top packer seal. See Section 3B.7.5.6.

   Also, see Section 6B.4 for step-by-step procedures regarding installation and removal of the multi-zone monitoring system.

a. Under normal operating conditions, monitoring of the pressure inside the tubing will be carried out continuously using a pressure gauge at the wellhead. Manual readings of the fluid level inside tubing will be collected as part of standard operating procedures for all other activities (tubing open to atmosphere). An unexpected change in the water level inside the tubing will be investigated to confirm that it is not indication of a loss of hydraulic integrity. .

2) Continuous measurement and recording of fluid pressure/temperature will be carried out using the downhole pressure probes and temperature sensors located at select monitoring zones. Automated measurement of fluid pressure and temperature is intended from each of the perforated monitoring zones. Observed differential pressures between perforated zones provide on-going confirmation of effective annular seals between monitoring zones. As part of the Mechanical Integrity Testing System, an additional pressure probe will be used to continuously measure and record fluid pressure above the uppermost packer.

3) Baseline cased-hole logs will be run prior to injection and can be run on a repeat basis if conditions warrant. The profile inside of the tubing will allow passage of cased hole logging tools [e.g. Temperature, Pulse Neutron Capture (PNC), also known as Sigma or RST]. In the event of a compromised seal where CO_2 enters the annulus, the PNC tool will be used to identify unexpected CO_2 independently of the downhole pressure/temperature measurements.

In the event that the routine monitoring activities detailed above are inconclusive, a range of additional test procedures could be employed to further investigate any data irregularities and if necessary determine an appropriate remedial action. If in-place remediation cannot be carried out, the multi-zone monitoring system can be removed. Procedures for this removal are outlined elsewhere in this permit application. (Section 6B.4 Contingency Plan)

Temperature Logging and Time Lapsed Formation Sigma Logs

To verify the "absence of significant fluid movement," time-lapse formation sigma logs can be run and data recorded across the entire interval from the deepest reachable point in the Mt. Simon to, at a minimum, the Maquoketa Formation (the lowest alternative confining zone). The initial sigma log will include temperature data and will be run before CO_2 injection to establish a pre- CO_2 baseline to compare with the post injection logging runs. Logs will be run under static conditions, presumably with tubing in the well, although valid data can and will be acquired should tubing be pulled for any unforeseen reasons. If any subsequent surveys are performed during the CO_2 injection period, the evaluation shall also include a temperature log to further detect fluid movement. The temperature log shall be run over the same intervals and at the same conditions as the sigma logs. Should either evaluation method (sigma or temperature log) detect significant fluid movement above the seal, oxygen activation logging methods may be used to further quantify the flow and aid in establishing a remediation plan. Details of Schlumberger's version of these tools are described below:

<u>Pulsed Neutron Capture Logging</u>

Reservoir Saturation Tool (RST) - Designed for reservoir complexity
Within the last decade, nearly every aspect of reservoir management has grown in complexity. What once was the exception is now routine: multiple-tubing and gravel pack completions, secondary and tertiary recovery, highly deviated wellbores, and three-phase production environments. The RSTPro* Reservoir Saturation Tool helps manage complexity by delivering reliable, accurate data. Run on the PS Platform string, with its suite of cased hole reservoir evaluation and production logging services, the RSTPro* tool uses pulsed neutron techniques to determine reservoir saturation, lithology, porosity, and borehole fluid profiles. This information is used to identify bypassed hydrocarbons, evaluate and monitor reserves in mixed salinity and gas environments, perform formation evaluation behind casing, and diagnose three-phase flow independently of well deviation.

An electronic generator in the RSTPro* tool emits high-energy (14-meV) neutrons in precisely controlled bursts. A neutron interacts with surrounding nuclei, losing energy until it is captured. In many of these interactions, the nucleus emits one or more gamma rays of characteristic energy, which are detected in the tool by two high-efficiency scintillators. High-speed digital signal electronics process and record both the gamma ray energy and its time of arrival relative to the start of the neutron burst. Exclusive spectral analysis algorithms transform the gamma ray energy and time data into concentrations of elements (relative elemental yields).

Formation sigma, porosity, and borehole salinity
The RSTPro* tool measures formation sigma, porosity, and borehole salinity using an optimized Dual-Burst* thermal decay time sequence. The two principal applications of this measurement are saturation evaluation, which relies on measurement accuracy, and time-lapse monitoring, where sensitivity is determined by measurement repeatability. A higher degree of accuracy in the formation sigma measurement is achieved by combining high-fidelity environmental correction with an extensive laboratory characterization database. The accuracy of RSTPro formation sigma is 0.22 cu for characterized environments and has been verified in the Callisto and American Petroleum Institute industry-standard formations. Formation porosity and borehole salinity are either computed in the same pass or input by the user. Exceptional measurement repeatability makes the RSTPro tool more sensitive to minute changes in reservoir saturation during time-lapse monitoring. The gains in repeatability and tool stability are the result of higher neutron output and sensor regulation loops. At the typical logging speed of 900 ft/hr [275 m/hr] for time-lapse monitoring, RSTPro repeatability is 0.21 cu.

Water velocity (Oxygen activation logging)
The RSTPro WFL* Water Flow Log measures water velocity by using the principle of oxygen activation. Gamma ray energy discrimination and tool shielding reduce the background from stationary activation, improving sensitivity in low-signal environments such as flow behind casing.

The cased-hole logging tools (e.g. the Reservoir Saturation Tool – RST) can pass through the tubing (since there will be no tubing restrictions smaller than 2.25”) and log the near-wellbore environment behind the well casing. The cased-hole logs are not adversely affected by the multi-zone monitoring system such that the tubing does not need to be removed during the RST and other cased-hole wireline logging techniques.

6B.3.1 Continuous Monitoring of Annular Pressure

Continuous annular pressure monitoring will also be used to verify mechanical integrity of the well. The pressure data will be transmitted to the ADM control room for monitoring and will be recorded at the same frequency as the injection well data (frequency) and reported monthly. If a pressure increase greater than 100 psi over atmospheric pressure is observed, or if pressure drops below 95% of atmospheric pressure (i.e. < 14.0 psi), an alarm will be triggered and the cause will be investigated. An example of the operational monitoring data for pressure is included on Figure 6B-1 "*Example Field Log Form for Manual Verification Well Gauge Readings*". The annular space will also be checked quarterly to verify that the annulus is full; fluid will be replaced as needed. This observation will be noted in the operating report. Pressure fluctuations in the range (or possibly exceeding the range) noted above are likely to occur immediately following well construction, sampling, and well workovers but would not be indicative of well integrity issues. Notation of these events will be included in the monthly reports. In the event of a power outage, manual readings will be taken and recorded.

In addition the following section describes the mechanical integrity testing of the wellbore across the multi-level monitoring system.

The multi-zone monitoring system is designed to incorporate a high degree of quality assurance testing and verification to confirm mechanical integrity of the system and the presence of packer seals between monitoring zones

Monitoring is intended to be carried out at multiple levels within the Mt. Simon injection horizon. A monitoring program will be utilized to confirm the presence of annular seals above the uppermost monitoring zone, and particularly to document the performance of the annular seals which isolate the individual zones and also prevent the movement of fluids into the overlying stratigraphic units.

The multi-zone monitoring system is compatible with the expected site subsurface environment (brine and CO_2) and elastomers present in the System will be CO_2 resistant. Thus, loss of mechanical integrity or component failure leading to the potential for vertical migration of fluid in the annulus is not expected. However, a number of methods, including wireline and pressure and temperature measurements, will be used to monitor system integrity and to verify the absence of vertical fluid movement within the well. These methods are implemented during the multi-zone monitoring system installation and during ongoing monitoring well operations, as described below.

During the installation process, a thorough QA procedure is followed to document the system performance, including:

- testing the hydraulic integrity of each tubing joint as the tubing string is assembled, providing baseline data confirming that the assembled joint is sealed and not a pathway for vertical movement of formation fluids

- testing the hydraulic integrity of the entire tubing string once the tubing has been lowered into place, again providing baseline data confirming that the tubing string is sealed and not a pathway for vertical movement of formation fluids

After the packers have been set, fluid pressure profiles and cased-hole logging will be carried out to establish baseline conditions of the well.

6B.3.2 Annual Testing

The annulus between the long string and the tubing above the uppermost packer will be pressure tested to 300 psi for one hour with a maximum of 3% leakoff allowed (see procedure in Section 3B.7.5). This test will be performed at least once per year and results will be reported in the next operating report. Following the annual test, the remaining pressure will be bled off to atmospheric and the annular space will be shut in.

6B.3.3 Ambient Pressure Monitoring

Continuous measurement and recording of fluid pressure/temperature will be carried out using the multi-zone monitoring system, which consists of pressure probes located at select monitoring zones. Automated measurement of fluid pressure is intended from each of the perforated monitoring zones. It should also be noted that the observed differential pressures between perforated zones will provide an ongoing confirmation of effective annular seals between monitoring zones.

6B.3.4 Corrosion Monitoring Plan

Cased hole logs (Multi-finger caliper, Ultrasonic Cement Evaluation) will be run during the initial verification well completion to provide baseline measurements of the long string casing internal diameter and thickness. This will allow for a comparison to subsequent logs if conditions suggest a need to re-run logs.

6B.4 Contingency Plan for Well Failure or Shut In

If necessary, the tubing string can be retrieved from the well. While this may not be the first course of action in response to information from the integrity monitoring measurements, this option is available if required.

The verification well will be remediated under the following conditions:

1) Abnormal annular pressure readings are observed.

Following the MIT, the remaining pressure will be bled off to atmospheric and the annular space will be shut in. If a pressure increase greater than 100 psi over atmospheric pressure is observed, or if pressure drops below 95% of atmospheric pressure (i.e. < 14.0 psi), an alarm will be triggered and the cause will be investigated.

2) Abnormal pressure / water levels are observed inside the tubing.

If there are pressures measured 100 psi over static levels or if pressure drops below 95% of atmospheric pressure (i.e. < 14 psi) inside the tubing an alarm will be triggered. Further investigation will be conducted as to the cause of the abnormal pressure reading, and remediation planned.

3) Suspicion that the well integrity has been compromised.

4) Surface equipment has been damaged.

If any of above should occur, steps will be taken to identify and correct any equipment deficiencies. Many interventions can be carried out using the multi-zone monitoring system to affect repairs and re-establish well bore integrity. Only if none of these interventions were successful then plans to remove the system from the well would be put in place. If required, retrieval of the tubing string would be done with BOPs in place according to the following summarized procedure:

1) Secure well until a workover rig and support equipment can be mobilized. Notify permitting agency of planned workover.

2) Rig up workover rig with pump and tank. Bleed down any pressure. Fill both tubing and annulus with kill weight fluid.

3) Begin to release all packers. Open appropriate sliding sleeve(s), and attempt to circulate fluid at very low rate. Close sliding and proceed to next packer.

4) When all packers are released, remove plug (if a plug was placed in bottom of string) and attempt to slowly circulate the well with kill weight fluid.

5) Prepare to remove tubing string from the well while carefully keeping the hole full of kill-weight brine. Pull tubing slowly as to not over-pull the designed strength of the tubing.

6) Remove tubing from the well and examine to identify the cause of the anomalous pressure.

Upon removal, a decision will be made as to whether to repair and replace or to plug and abandon the well.

The plan for the verification well includes but is not limited to the following:

1) A modified master and single wing wellhead assembly. Since these wells are not injection wells, wing valves will not have an automatic shut-down system but will employ manual gate valve assemblies which will be closed during normal operations.

2) All annuli will have pressure gauges installed. Gauges to be 0 to 150 psi operating range.

3) Under normal operating conditions, the well is essentially shut in and will be open only for testing, sampling, and maintenance. See Figure 3B-4 for wellhead diagram.

In the event of a power outage, manual readings of the pressure in the tubing and annulus will be taken and recorded every four hours until power is restored. Note that in the event of a power outage, the injection well will be shut in.

6B.4.1 Persons Designated to Oversee Well Operations

A site-specific list of persons designated to oversee well operations in the event of an emergency shall be developed and maintained during the life of the project.

6B.5 Quality Assurance Plan

See Section 6A.5

6B.6 Reporting Requirements

See Section 6A.6

Figure 6B-1. Example Field Log Form for Manual Verification Well Gauge Readings

FIELD LOG – INJECTION / VERIFICATION WELLS
(For back up field data collection in the event of power outage or other data transmission loss from automated gauges – see "*Instructions"*)

USEPA Site #1150155136 – Macon County Archer Daniels Midland – Corn Processing Carbon Sequestration Injection and Verification Wells	Permit No. Well No. UIC Log #

ADM Supervisor: ____
Readings Taken by: Name:____
Phone:____

Check Box(es) Above Failed Instrument(s) ➔						
DATE	**TIME**	**Injection Wellhead Pressure** PIT-009 (psig)	**Injection Annulus Pressure** PIT-014 (psig)	**Verification Tubing Pressure** (psig)	**Verification Annulus Pressure** (psig)	**INITIALS**

INSTRUCTIONS – *Within 30 minutes of a communication loss, manual readings of the pressure in the tubing and annulus of both wells will be taken and recorded, and continued every 4 hours thereafter until communication is restored.*